Code of Practice

Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants

Version 2 - March 2014

Code of Practice for the Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants

In order to support the increasing use of hydrocarbon refrigerants in integral commercial refrigerated cabinets the British Refrigeration Association Cabinet and Cold Store Section has commissioned this Code of Practice. It clarifies the regulations, standards and practices which apply to the leak simulation testing and subsequent design of systems which use hydrocarbon refrigerants. This will provide the basis for a consistent approach to be adopted by all manufacturers, end users and specifiers when using these refrigerants.

Ian Garvey
Chairman of BRA Cabinet & Coldstore Section Hydrocarbon working group

Disclaimer

FETA uses its best efforts to promulgate Standards and Guidelines for the benefit of the public in the light of available information and accepted industry practices but do not intend such Standards and Guidelines to represent the only methods or procedures appropriate for the situation discussed. FETA does not guarantee, certify or assure the safety or performance of any products, components, or systems tested, installed or operated in accordance with FETA's Standards or Guidelines or that any tests conducted under its Standards or Guidelines will be non-hazardous or free from risk.

FETA, and the individual contributors, disclaims all liability to any person for anything or for the consequences of anything done or omitted to be done wholly or partly in reliance upon the whole or any part of the contents of this booklet.

Code of Practice for the Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants

March 2014

This Code of Practice was originally prepared by Cool Concerns Ltd at the request of the Council of the British Refrigeration Association (BRA) because of the increase in demand for refrigerated cabinets running on hydrocarbon (HC) refrigerants. Cabinets that are designed and manufactured in accordance with this Code meet basic safety principles with regard to the application of a flammable (A3) refrigerant.

This Code should be read in conjunction with the standards summarised in Appendix 2.

Revision

This code is a revision of the original published in January 2012; the revision has been undertaken by the original authors, Cool Concerns Ltd, in March 2014.

Scope

This Code defines standards in the design and manufacture of integral (plug in and hard-wired) and close coupled remote type cabinets for food display, service and storage (stand alone and multiplexed). It is aimed at cabinets with a charge size greater than 150 g. It is also applicable to cabinets with less than 150 g, but for these cabinets other standards, including 60335-2-24:2010 and 60335-2-89:2010, also apply. These standards are also often used for Low Voltage Directive (LVD) and Electromagnetic Compatibility (EMC) directive compliance.

ATEX

ATEX is the name commonly given to the legal requirements for controlling explosive atmospheres and the suitability of equipment and protective systems used in them. HC systems can leak refrigerant and create a potentially explosive atmosphere around them, therefore we need to follow the principles of ATEX with regards to removing any potential sources of ignition within a zone that could contain a potentially flammable atmosphere in the event of refrigerant leakage. Guidance on achieving this can be found in this document.

Applicable Standards and Acceptable Charge Sizes

There has been continued discussion and disagreement across some European countries regarding hydrocarbon systems being acceptable or legal with charge sizes above 150g. HCs were primarily deployed in the domestic sector (white goods) and entered the commercial sector in domestic derived equipment with charge sizes below 150g. The applicable standards for these systems are in the EN60335 range which clearly state they are for systems with charge sizes up to 150g of flammable refrigerant and that above 150g other standards would apply. EN378 covers fixed and stationary systems (including appliances) with charge sizes above 150g. ISO5149 follows similar principles internationally.

Sub 150g HC systems can be located in any occupancy and room size but potential sources of ignition associated with the system construction are still considered during design. Sources of ignition beyond the footprint of the equipment are not considered relevant due to the charge size: 150g requires a room smaller than $4m^3$ to reach the lower flammability level and any probable leak of refrigerant will be much less than this in reality.

Commercial systems above 150g are specified and constructed according to EN378 which also mandates EN60335 and EN60079 for electrical safety. This guide has been based on the requirements of EN378 for achieving safe system design and construction of systems above 150g albeit the principles adopted are almost identical across the standards concerning HC's.

There are no barriers to the construction of systems using HC refrigerant above 150g providing the correct application of the appropriate standard/s. A summary of the directives and standards can be found below and a more detailed explanation can be found in the table of Appendix 2 and throughout this code of practice.

Directives:

- ATEX 137 (99/92/EC - Workplace) – DSEAR (The Dangerous Substances and Explosive Atmosphere Regulations)
- ATEX 95 (94/9/EC - Equipment) – ESP (The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmosphere Regulations)
- Pressure Equipment Directive (97/23/EC)

Standards & Codes:

- EN 378:2008/9 Parts 1-4
- IoR Code of Practice – A2 & A3 Refrigerants
- EN 60335 – Various Parts
- EN 60079 – Various Parts

Table of Contents

1. Introduction

This section provides basic information about hydrocarbon refrigerants.

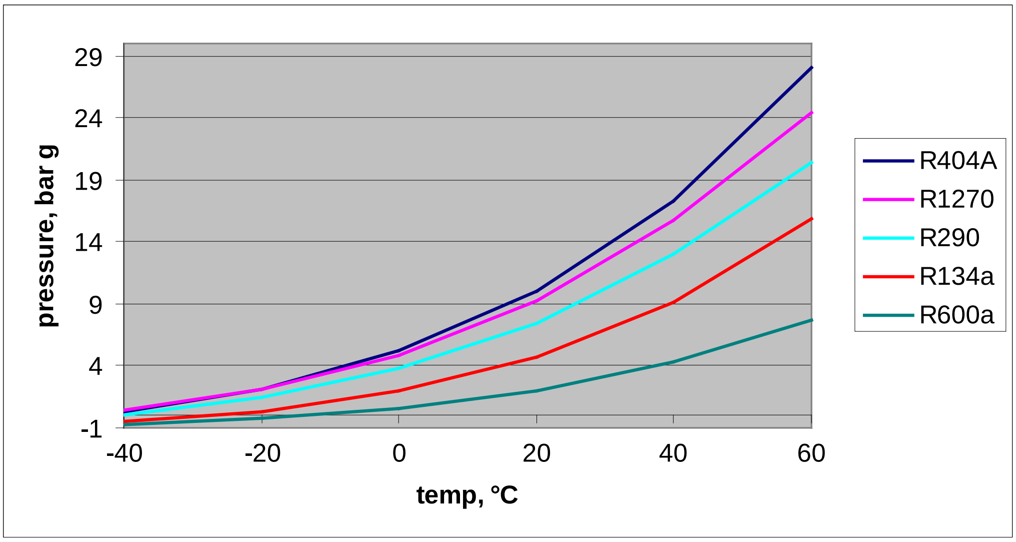
End users are increasingly specifying hydrocarbon (HC) refrigerants in cabinets, mainly due to their low global warming potential and good energy efficiency. The range of HCs available is shown below. The hydrocarbons predominantly used in commercial refrigeration systems are R290 and R1270. R600a is used in some small commercial systems, but is mostly used in domestic systems.

	Refrigerant number	Trade name
Propane	R290	Care 40
Propene (propylene)	R1270	Care 45
Iso Butane	R600a	Care 10

The chart (right) shows an approximate cooling capacity comparison between HCs and HFCs. The actual comparison depends on operating conditions and compressor technology. Generally the energy efficiency is up to 20% better than for HFCs. The latent heat of HCs is up to 2.5 times higher and the heat transfer up to 1.5 times higher than for HFCs. The density is approximately 45% that of HFCs.

The graph below shows the relationship between pressure and saturation temperature. Accurate data can be obtained from software such as Coolpack [1].

[1] Coolpack can be obtained from http://www.et.web.mek.dtu.dk/coolpack/uk/download.html



pressure, bar g
29
24
19
14
9
4
-1
-40
-20
0
20
40
60
temp, °C
R404A
R1270
R290
R134a
R600a

2. Flammability

This section provides information about the flammability of HCs, sources of ignition and charge size limits.

Flammability information is shown in the table below [2].

	PED fluid group	Practical limit (kg/m^3)	Lower flammability limit (LFL, kg/m^3)	Lower flammability limit (LFL, %, by volume of air)	Auto ignition temperature, ^oC
R600a	1	0.008	0.043	1.8	460
R290	1	0.008	0.038	2.1	470
R1270	1	0.008	0.040	2.0	455

If the concentration of HC in air is between the LFL and the UFL (upper flammability level, approximately 10%) the refrigerant can be ignited. Sources of ignition include unsealed (sparking) electrical switches and naked flames. More information about electrical sources of ignition is in section 5.

2.1 HC system classification

Under ATEX areas are classified according to the hazard associated with the flammable gas. Account is taken of the likelihood of an explosive atmosphere occurring and its persistence if it does. The following classifications typically apply to refrigerated cabinets.

- Zone 2 – area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short time only [3].
- Secondary grade of release – release which is not expected to occur in normal operation and, is it does is likely to do so only infrequently and for short periods [4].
- Equipment category 3G – equipment suitable for zone 2.
- Electrical equipment of group II is intended for use in places with an explosive gas atmosphere other than mines susceptible to firedamp (flammable gases such as methane). Group II is sub divided; group IIA includes gases such as propane [5].

Under EN378-1:2008A2:2012, HC refrigerants are classified in Safety Class A3 – they have higher flammability and lower toxicity.

[2] EN378-1:2008 A2:2012, Annex E
[3] EN60079-10-1:2008, 3.8
[4] EN60079-10-1:2008, 3.10
[5] EN60079-0, 4.2

2.2 Charge size restrictions

Flammability restricts HC charge sizes – A factory sealed system with a charge less than 150g of A3 refrigerant can be located on any occupancy without restriction. Above 150g maximum charge sizes and the practical limit are specified in EN378-1:2008 A2:2012. The practical limit is used if the HC refrigerant could leak into an occupied space, for example a supermarket shop floor or preparation area, or into a cold room (see example, below). In addition there are maximum charge sizes dependent on the occupancy category. Whichever is the lowest charge applies.

Example of practical limit
In a preparation room 3m by 5m by 2.5m high each HC system cannot have more than 0.3kg charge.
Max charge = 5m x 3m x 2.5m x 0.008kg/m^3 = 0.3 kg

The following is an extract from EN378-1:2008 Table C.1 which provides maximum charge sizes for a range of occupancies and equipment types. The information below would encompass most integral refrigerated cabinets for the retail sector.

Location of the refrigeration system	Occupancy	Maximum charge per system
Human occupied space and occupied machinery rooms	General occupancy – Class A	Only sealed systems with Max charge = practical limit x room volume and not exceeding *1 kg below ground floor level* and 1.5 kg above ground floor level
Human occupied space and occupied machinery rooms	Supervised occupancy - Class B	Only sealed systems with Max charge = practical limit x room volume and not exceeding 1 kg below ground floor level and 2.5 kg above ground floor level

The information in italics has been added by the authors as it is not currently included in EN378 this error will be corrected in revisions going forward.

General occupancy - Class A is where the number of people present is not controlled or to which any person has access without being necessarily acquainted with the general safety precautions. An example is a supermarket shop floor.

Supervised occupancy - Class B is rooms, parts of building or buildings where only a limited number of people may be assembled, some of them being necessarily acquainted with the general safety precautions. Most designers assume an occupancy class A because the definition of occupancy class B is difficult to control in reality.

Refer to EN378-1:2008 A2:2012 Table C1 for full information, including limits for indirect systems, and for systems or parts of system located in machinery rooms or outside etc.

3. Introduction to the Design Process

This section outlines the process necessary to ensure HC systems are safe. More detailed information is provided in subsequent sections.

A leak of HC refrigerant can potentially result in a flammable zone around the system. Sources of ignition within the potentially flammable zone will present a hazard in the event of a leak. An essential part of the design process is to ensure there are no sources of ignition inside potentially flammable zones. This can be achieved by ensuring leaks do not result in a flammable zone or by removing sources of ignition from the flammable zone.

The process for ensuring HC systems are safe is summarised below for any system which contains sources of ignition, regardless of the charge size.

Step 1	Carry out flammable zone testing (area classification) to determine the extent of the potentially flammable zone in the event of a leak. *See section 4.*

↓

Step 2	Identify sources of ignition within the potentially flammable zone. *See section 5.*

↓

Step 3	Option 1 or	Move the source of ignition outside the potentially flammable zone. EN60079-14 requires that, wherever possible, electrical equipment should be located in non-hazardous areas [6].
	Option 2 Or	Replace the source of ignition with a suitable device. *See section 5.*
	Option 3 or	Increase the air flow and / or maintain a permanent air flow to reduce the potentially flammable zone. *See section 6.*
	Option 4	Locate the source of ignition in a suitable enclosure (this is usually cost prohibitive for small systems and difficult to achieve). *See section 5.*

More detailed information on each of the above is shown in subsequent sections as indicated.

[6] EN60079-14:2008, 4.1

3.1 Reducing leak potential

The potential for leakage should be reduced as much as is practical. Consideration should be given to:

- Minimising the number of joints;
- Quality of brazing and brazing procedures;
- Competence and qualification of brazers[7];
- Method of access to the system for service:
    - Capped Schrader valves on both the high and low sides of the system should be used. The correct Schrader core should be specified for the refrigerant, oil, pressure and temperature. It should be removed when brazing in the Schrader body, and re fitted to the correct torque when the body is cool;
- Quality of pipe bending;
- Vibration elimination;
- Minimising the potential for chafing;
- Minimising potential for exposure to damage;
- Protecting pipe work from corrosion, e.g. discharge pipe work which evaporates defrost condensate;
- Pressure testing for strength and leak tightness before charging in accordance with EN378.

[7] Jointing of Copper Pipework for Refrigeration Systems - Specification & Procedures for Manual Torch Brazing and Brazer Assessment Issue 4 – May 2012

4. Simulated Leak Testing

This section covers the simulated leak testing required to determine the extent of a potentially flammable zone in the event of a leak.

Simulated leak testing is carried out to determine the extent of a potentially flammable zone in the event of a leak. The test work should comply with EN66079-10-1. The procedure below summarises the process, and further detail is provided within this section, but reference should be made to the standard for full information.

Step 1	Identify potential leak location(s) (see section on Test Work for further information).
Step 2	Calculate the release rate from EN60079-10-1, Annex A for each location. The following needs to be determined: • The hole size of the leak; • Whether the release will be liquid or gas ; • The maximum pressure and temperature of the refrigerant at the point of leakage.
Step 3	Decide whether there will be air flow. If fans run permanently then they can run during the test. If fans switch off when the refrigeration system is off (on temperature for example) they should not be run during the test, i.e. testing should be carried out at worst case scenario conditions.
Step 4	Carry out the leak simulation test, measuring the HC concentration where there are sources of ignition and around the system to find the extent of the potentially flammable zone (area classification).
Step 5	Record the test work in a technical file.

4.1 Release rate calculation

Release rate calculations are given in EN60079-10-1[8] for leaks of both liquid and gas. These models do not account for volatile fluids. The liquid release calculation gives an overly onerous release rate and is not usually used in refrigeration systems because at the actual point of leakage, for example in a liquid line, the refrigerant will either be two phase or gas very shortly after the leak starts. It has been acknowledged that the calculations in EN60079-10-1 produce onerous release calculations and this has been confirmed by testing.

Catastrophic leaks do not need to be considered[9].

The table below shows the maximum pressures and temperatures that should be used:

	Max pressure (p), bar g [10]		Max temperature (T), °C	
	Low side	High side	Low side	High side
R290	10.3	18.1	32	55
R1270	12.7	21.8	32	55
R600a	3.3	6.8	32	55

Numerous manufacturers have considered hole sizes between 0.25mm and 1.25mm diameter adequate for leak simulation testing and these represent onerous refrigerant leaks. The determination of the appropriate hole size needs careful consideration and should represent what is possible depending on the particular construction of the system.

Additional guidance on leak simulation can be found in EN60335-2-89[11] Section 22.108 and considers the simulated leakage rate to be 50% of the refrigerant charge released at a constant over 1 hour.

4.2 The test work

The leak simulation testing should be carried out in an environment similar to that where the system will be located. Natural airflow rates in the testing environment should be limited to below 0.2m/sec [12] so as not to adversely influence the dispersion of HC refrigerant. Consideration should be given to room size and adjacent equipment with regards to ignition sources during the testing.

Potential leak points typically include joints, a bend of more than 90°, pipe and components which are exposed to damage and any other weak point in the system.

The HC release is typically from a cylinder via a tube to the leak location on the system. The leak can either be:

[8] EN60079-10-1 A.3.2.1 Release rate of gas with choked gas velocity
[9] EN60079-10-1:2008 1 note d and note 5
[10] Based on 32°C and 55°C in accordance with EN378-1:2008 A2:2012
[11] EN60335-2-89 Household and similar electrical appliances — Safety Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor
[12] In line with performance testing standard ISO EN23953 5.3.1.2

- Through the determined hole size with the refrigerant at the maximum system pressure, connected to the cylinder's liquid or gas off take as required. The refrigerant pressure should be as specified in the table above. It is recommended that the leak rate is recorded. The photo shows assemblies used for simulated leak testing with hole sizes of 0.35 mm and 1.1 mm diameter;

or

- Through an adjustable metering valve at the rate calculated by one of the equations above. The photo shows a needle valve used for leak simulation testing, capable of metering the release at the required rate.

Care should be taken to ensure that the installation of the leak, the positioning of the refrigeration system and the refrigerant sampling equipment do not notably influence the test results. The equipment for measuring the refrigerant concentration should have sufficiently rapid response to changes in concentration, typically 2 to 3 seconds. If the measuring method is one that removes gas samples, then it shall do so at a rate less than 4 ml per minute [13]. The concentration can be measured using a meter such as that shown in the photo (BW Technologies Gas Alert Micro 5).

Any location where the concentration is above 50% of the LFL for any part of the test is deemed to be potentially flammable [14]. The factor of 0.5 is used because an HC refrigerant leak is defined as a secondary release.

Section 5 shows how to deal with sources of ignition within potentially flammable areas.

4.3 Adjacent equipment

The simulated leak testing also identifies the area around a system which must be free from sources of ignition. If a potentially flammable zone can occur beyond the footprint of the HC equipment it is important that other equipment located within this area is suitable for use in a potentially flammable environment.

[13] Institute of Refrigeration Code for A2 and A3 refrigerants.

[14] EN60079-10-1:2009 B.5.2.1, 2

For cabinets with doors where HC could leak inside the cabinet, testing should be carried out to determine the extent of a potentially flammable zone when the door(s) are opened after a leak into the cabinet.

4.4 Reporting

Recording the results of the simulated leak testing provides evidence of compliance with the principles of ATEX and demonstrates to end users that leak simulation testing has been carried out to the relevant standard. The following information should be included:

- Refrigeration / air conditioning system (make and model) tested;
- Leak rate and leak positions;
- Standards used to determine the release rate and maximum allowable concentration;
- Explanation of test methodology;
- Equipment used and relevant calibration information;
- Refrigerant information;
- Assumptions made such as maximum pressure and temperature where relevant;
- Air flow rate during the test associated with the equipment and external;
- Test results - concentration measured at each location throughout test. It is recommended that this is presented as a graph of the %LFL against time for each leak location, with photos showing the location of the leak and sensor.

5. Electrical Devices – Types and Enclosures

This section summarises the requirements for electrical devices, enclosures and connections used in potentially flammable atmospheres. It is not possible to include full and detailed information in this Code. The relevant standards are included and must be referred to for specific information.

The simulated leak testing will identify sources of ignition which are within the potentially flammable zone. Electrical devices within the potentially flammable zone must not:

- Produce an operational arc or spark (unless that arc or spark is prevented from causing ignition in accordance with IEC EN60079-15, clauses 16 to 20);

- Develop a maximum surface temperature in excess of the maximum appropriate to the temperature class of the apparatus (unless the temperature is prevented from causing ignition in accordance with IEC EN60079-15, clauses 16 to 20).

Sources of ignition associated with refrigerated cabinets typically include:

- On / off switches or contactors;
- Relays (e.g. on controls and single phase compressors);
- Pressure switches;
- Thermal overloads;
- Fan motors;
- Thermostats;

- Condensate pumps;
- Miniature circuit breakers (MCBs);
- Defrost heaters if the surface temperature can exceed 360^{O}C (maximum heater surface temperature should be demonstrated by testing in the operating environment maximum ambient, assuming defrost termination has failed).

This is not an exhaustive list, but includes the most common electrical devices which need to be considered.

The following items are generally not sources of ignition:

- Cabinet lighting (the switch, starter and terminations must be considered even for low voltage lighting),
- Capacitors (it is recommended that bleed resistors are fitted to minimise the hazard caused by discharge during service);
- Solenoid valve coils;
- Wiring connections (accidental disconnection, for example during service, can produce a spark. To minimise this risk with push crimp terminals, tagged terminations that cannot be accidentally disconnected are recommended);
- Fuses (deemed non sparking devices if they are non-rewirable, non-indicating cartridge types or indicating cartridge types, according to IEC60269-3, operating within their rating [15]).

There are various options for dealing with sources of ignition within a potentially flammable zone. In order of simplicity and effectiveness they are:

1. Move the source of ignition outside the potentially flammable zone.

   Or

2. Replace the source of ignition with a suitable device.

   Or

3. Increase the air flow and / or maintain a permanent air flow to reduce the potentially flammable zone.

   Or

4. Locate the source of ignition in a suitable enclosure which meets the requirements of EN60079-15:2010 (this is usually cost prohibitive for small systems).

Air flow is covered in the next section. The remainder of this section covers safe electrical devices and enclosures.

[15] EN60079-15:2010, 9.1

5.1 Electrical devices for use in potentially flammable atmospheres

IEC EN60079-15 defines type "n" protection as that which, in normal operation and in certain specified abnormal conditions, is not capable of igniting a surrounding explosive gas atmosphere. Switching electrical devices which are located in a potentially flammable atmosphere should therefore be type "n" in accordance with IEC EN60079-15, which includes different types of protection as follows:

- "nA" – non sparking (device constructed to minimise the risk or occurrence of arcs or sparks capable of creating an ignition hazard during conditions of normal operation [16]).
- "nC" – enclosed break (device incorporating electrical contacts that are made and broken and that will withstand an internal explosion of the flammable gas or vapour which may enter it without suffering damage and without communicating the internal explosion to the external flammable gas or vapour [17]).
- "nC" – hermetically sealed device (device which is so constructed that the external atmosphere cannot gain access to the interior and in which the seal is made by fusion, for example by soldering, brazing, welding or the fusion of glass to metal [18]).
- "nC" – non-incendive component (components having contacts for making or breaking a specified ignition capable circuit but in which the contacting mechanism is designed and constructed so that the components is not capable of causing ignition of the specified explosive gas atmosphere [19]).
- "nC" – sealed device (device which is so constructed that it cannot be opened during normal service and is sealed effectively to prevent entry of an external atmosphere[20]).
- "nR" – restricted breathing (enclosure that is designed to restrict the entry of gases, vapours and mists [21]).

Some electrical devices used in refrigeration systems meet the requirements of IEC EN60079 type "n" protection, but have not been tested to confirm this. Devices which are type "n" must be tested by an approved notified body and correctly documented.

5.2 Cabinets with doors and wells

In the event of a leak into a cabinet with doors the refrigerant cannot disperse if the doors remain closed, e.g. out of trading hours. The persistence time above the LFL is therefore greater than with open cabinets. This affects the area classification – the inside of the cabinet should be treated as a zone 2 area. Fan motors should comply with EN60079-15 or be Ex rated (spark free, suitable for a Zone 2 area). Other sources of ignition should be

[16] EN60079-15:2010, 3.7.1
[17] EN60079-15:2010, 3.7.2.1
[18] EN60079-15:2010, 3.7.2.2
[19] EN60079-15:2010, 3.7.2.3
[20] EN60079-15:2010, 3.7.2.4
[21] EN60079-15:2010, 3.7.3. The specific testing can be found in EN60079-15, 22.6.

removed from the inside of the cabinet such as door switches and heater klixons or replaced with suitable electrics tested to EN60079-15.

The above might also apply to well type cabinets. Testing should be carried out to check the concentration in the well in the event of a leak. If it is greater than 50% LFL the above will apply.

Consideration should be given to the area in front of cabinet with doors which could also be a zone 2 area when the doors are opened during / after a refrigerant leak. Measurements should be carried out in front of the cabinet to determine the extent of the zone.

Testing carried out on cabinets with doors or wells should record the duration that 50% LFL was exceeded (i.e. the persistence time).

A refrigerant leak detector could be fitted into the enclosed space to isolate all electrical circuits as an ultimate protection. The detector should activate at the practical limit (0.008kg/m^3 or approximately 4000 ppm). Due to the nature of the operating environment and long term maintenance the detector would be deemed as 'fallible' so cannot act as a primary protection method.

5.3 Enclosures

Sparking electrical devices can be located in a sealed enclosure within the potentially flammable zone. The enclosure must meet the requirements of IEC EN60079-15:2010. Any enclosure will be designated 'restricted breathing' due to its IP rating. The testing for this is onerous and difficult to apply physically and is usually cost prohibitive.

5.4 Connection / disconnection

Electrical connections within a potentially flammable zone are hazardous if disconnected while energised.

Plugs and sockets, if they are allocated and connected to only one part of the equipment, shall be secured mechanically to prevent unintentional separation or have a minimum separation force of 15 Nm. The equipment shall be marked as follows [22]:

WARNING – do not separate when energised.

Fuse enclosures shall be interlocked so that the fuses can only be removed or replaced with the supply disconnected or the enclosure shall carry the following warning label [23]:

WARNING – do not remove or replace fuse when energised.

The photo shows an example of a label on a display cabinet.

5.5 Wiring

Non sheathed single cores shall not be used for live conductors, unless they are installed inside switch boards, enclosures or conduit systems [24].

[22] EN60079-15:2010, 10.1 and 24.3.1
[23] EN60079-15:2010, 9.4
[24] EN60079-14:2008, 9.3.5

6. Air flow

This section covers the use of air flow to reduce the extent of the potentially flammable zone in the event of a leak and the application of theoretical Vz calculations.

Zone 2 of NE (Negligible Extent)

If it can be demonstrated that a theoretical flammable volume (Vz) is below 0.1m^3 or 1% of the ventilated volume (Vo), the Zone can be classed as a Zone 2 of NE (Negligible Extent). The calculation for Zone 2 NE can be found in EN60079-10-1, Annex B which provides information and formulas to allow the flammable zone to be calculated from the refrigerant leak rate, air flow, LFL, temperature and enclosure volume (Vo). If the resultant potentially flammable volume (V_z) is equal to or less than 0.1 m^3 or 1% of Vo, whichever is smaller, it is considered to be a Zone 2 of negligible extent.

The air flow associated with a refrigeration system's condenser fan/s is usually sufficient to reduce the potentially flammable area to a zone of negligible extent[25]. Leak simulation testing should be carried out to prove the results of any calculations as geometry and actual airflows achieved will influence dispersion of HC refrigerant. Any measurement exceeding 50% LFL indicates that the area could be potentially flammable in the event of a leak and that airflow on its own is not sufficient to protect sources of ignition. Serious consideration should also be given to fouled condensers or failed fan motors which would reduce available airflow significantly.

Table B.1 – Influence of independent ventilation on type of zone

Grade of release	Ventilation						
	Degree						
	High						
	Availability						
	Good	Fair					
Secondary[b]	(Zone 2 NE) Non-hazardous[a]	(Zone 2 NE) Non-hazardous[a]					

Ventilation Degree is **High** when an evaluation of the risk shows that the extent of potential damage due to the sudden increase in temperature as a result of ignition of an explosive gas atmosphere of volume = V_z, is negligible. This is normally when V_z is less than 0.1 m^3. Air flow associated with condenser fans is generally high.

Availability is **Good** when ventilation is present virtually continuously.

Availability is **Fair** if ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods.

[25] EN60079-10-1:2009, B.7

To avoid the need for changes to electrical devices or enclosures either:

- Condenser fans can be run constantly (i.e. not switched off when the system is down to temperature). This will increase the power consumption of the system;

  or

- A supplementary fan can be switched on when the condenser fan is off. Sufficient air flow is usually provided by a smaller fan than that used for condenser cooling, so the power requirement associated with this option is usually less than constantly running a condenser fan. The airflow of the supplementary fan must be tested with leak simulation to ensure the airflow is sufficient to disperse the HC refrigerant.

Note: Serious consideration should be given to fouled condensers or failed fan motors both reducing available airflow significantly, especially if they are the primary protection method for sources of ignition.

7. Labelling and Documentation

This section covers the labelling of systems charged with HC refrigerant.

Systems should be clearly labelled, with the ISO label (right), to show the refrigerant type and that it is flammable.

It is recommended that an additional label is fixed to the system to provide basic safety information to service engineers.   An example label for an R290 system is shown below.

Refrigerant R290 (Care 40, Propane)

This unit must not be located in a room or area with a volume less than XXX m^3.

Note: Only engineers who have been trained in the safe handling and use of hydrocarbon (HC) refrigerants should work on this system.

- Work on this system in a well ventilated area or outside.
- Use a local leak detector to indicate if there is hydrocarbon in the air around the system before and during work on the system (place it at low level - HCs are heavier than air).
- Ensure there are no sources of ignition (flames or sparking electrical components) within 3 m (10 feet) of your work area.
- If replacing components, use like for like replacements.
- Take great care when brazing to ensure all HC has been removed from the system.

Use refrigerant grade propane (R290 or CARE 40).

The minimum room volume is calculated using the practical limit (0.008 kg/m^3).

8. Manufacture

This section provides outline information about the aspects of manufacture related to the use of HC refrigerants.

Systems should be processed to ensure joints are safe and leak tight in accordance with EN378:

- Strength tested to 1.1 x PS;
- Leak tightness tested to 1 x PS, measured using a system with a sensitivity of 3g/year;

where PS is the system pressure as defined in EN378-1:2008 A2:2012.

The system should then be evacuated to 375 microns (0.375 Torr, 0.5 mbar) before charging.

The pressure testing for strength and leak tightness, the vacuum achieved and performance checks should be recorded.

Consideration should be given to the following points when designing the HC charging facility:

Accuracy of charge for critically charged systems. Because of the lower charge weight compared to HFCs, the tolerance can be as low as ±5g in commercial cabinets.

Location. The HC charging area must not be below ground level. There must be no below ground areas adjacent to the charging areas where leaking HC could collect.

Ventilation. Usually two levels of ventilation are used – low level for normal operation switching to a high level for emergency operation (e.g. in the event of an HC leak). The ventilation should extract air at low level from the charging area and discharge it to an area outside where HC will be safely dispersed. Fans and motors should be rated for use in a potentially flammable atmosphere.

Sources of ignition. An area around the charging equipment should be free from sources of ignition. Typically this will be an area 3 m from the equipment, but the actual zone will depend on ventilation, factory layout, leak detection etc.

HC gas detection. The type used should accurately sense the HC(s) being used, and not be affected by other airborne substances. An infra-red system will be the most reliable. The system should be properly commissioned and regularly checked. Sufficient sensors should be used to ensure a leak of HC refrigerant is detected. In this event the control system should switch on the high level ventilation and activate an alarm. The detection system should be set to activate at 20% LFL.

Storage of HC refrigerant. The minimum quantity of HC should be inside the charging area. All other HC cylinders should be stored outside in a safe area.

Operator training. Operators charging HC refrigerant and their supervisors should be trained in the safe handling of HCs (see section 10 for more information).

Access. Access to the HC charging area should be restricted to personnel who have received safe handling training. The area should be clearly marked with warning signs. The charging area should be easily accessible in the event of an emergency.

HC supply. Any pipe work associated with HC charging should be protected from accidental damage. The HC cylinder or vessel should be fitted with an excess flow valve.

Fire extinguishers. Fire extinguishers should be located in the charging area (dry powder or CO_2 types).

After charging the final joint(s) must be leak tested.

9. End User Post Installation Checks

End users usually drive the move to HC refrigerants, but where this is not the case they should be made aware that systems are charged with HCs. Where applicable, information about the minimum room size the equipment can be located in and the flammable zone around the cabinet should be provided.

It is recommended that the application and installation of HC cabinets are checked, for example by an independent expert. This should include confirmation that:

- The cabinet has been produced to specification;
- Its location is in accordance with EN378-1:2008;
- Sources of ignition are not located in a potentially flammable zone around HC cabinets;
- Appropriately trained and qualified engineers work on the cabinets.

10. Service and Repair

This section provides an outline of the service and maintenance of HC systems, where procedures and equipment differ from service of HFC systems.

10.1 Personal leak detection (monitors)

An HC gas detector should be used to monitor the air in the work area. The detector should not have a ‘zero background’ facility and should alarm at a maximum of 20% LFL. The engineer would need to determine the most appropriate place to locate the sensor dependent on the working environment. The photos show suitable detectors.

10.2 Tools and equipment

Standard (HFC) equipment can be used for servicing HC systems with the following exceptions:

- **Electronic leak detectors**. Most HFC leak detectors are not safe for use with HCs and are not sensitive to HCs. Electronic HC (combustible gas) leak detectors are available from a number of suppliers.

- **Recovery machines**. HFC recovery machines are not safe for use with HCs so one specially designed for use with HCs must be used.

- **Scales**. More accurate scales are necessary when charging HC systems with a small, critical charge. An accuracy of ±5 g is often necessary – most scales used for service are not this accurate.

Additional safety equipment is also required:

- A dry powder or CO_2 fire extinguisher.

- A suitable ventilation fan should be used when working inside if there is insufficient natural ventilation. An example is shown in the photo which has an Ex rated fan motor and a 5 m extension lead so the fan can be switched outside the 3 m work area.

10.3 Procedures

In general, good refrigeration practice should be followed when servicing HC equipment. Differences are outlined below.

- The work area must be well ventilated with no source of ignition within 3 m (typically) of the HC system and equipment such as a vacuum pump and recovery machine.

- The vacuum pump should be controlled by a switch outside the 3m zone (the vacuum pump's switch should not be used as it is a source of ignition). Care should be taken to ensure that the vacuum pump has no motor starters such as relays or centrifugal switches. The vacuum pump could discharge residual HCs so should be located in a well ventilated area.

- If the HC charge is less than 150 g it can be vented rather than recovered, providing it can be vented to outside a building and safely dispersed.

- Prior to un brazing joints the HC must be removed from the system, and the system filled with nitrogen. For system with more than 150 g charge the procedure is:

  1. Recover the HC from the system.
  2. Run the recovery machine for as long as possible so the system is under vacuum and as much of the HC charge is removed from the system as possible. Note - the machine commonly used for HC recovery (the Caresaver) can only be run for 5 minutes with the low pressure switch bypassed, but this should be sufficient.
  3. Fill the system with dry nitrogen to a slight positive pressure.
  4. Release the pressure and leave the system connected to the vent line and open.
  5. Unbraze connections as quickly as possible – wear gloves and goggles.

  Note – when recovering HC from large systems the process can be speeded up by recovering into evacuated, chilled recovery cylinders.

- Faulty electrical devices and compressors must be replaced with like for like components.

Further detailed guidance can be found in the BRA document '**Guidance for the Service of Hydrocarbon Refrigerant Equipment in a Retail Environment**.'

11. Training

This section outlines the topics to be included in training of service engineers and manufacturing personnel.

EN378 specifies that anyone working on HC systems should be trained to include the following [26]:

- Knowledge of legislation, regulation and standards relating to flammable refrigerants;

- Detailed knowledge of and skill in handling flammable refrigerants, personal protective equipment, refrigerant leakage prevention, handling of cylinders, charging, leak detection, recovery and disposal.

BOC specifies that anyone purchasing CARE (HC) refrigerant from them or HRP have either attended their awareness training session or hold a C&G 6187-21 qualification. They register trained engineers and issue photo ID cards. The BOC session covers the topics listed above.

City and Guilds 6187-21 is a hydrocarbon refrigerant handling CPD module. The following topics are included:

- Environmental benefits of using hydrocarbon (HC) refrigerants;
- Properties and hazards of HCs;
- Safe handling, including charging and recovery;
- Service procedures for HC systems including accessing and sealing systems, leak testing, brazing, evacuation and component replacement;
- Cylinders, cylinder storage and transport;
- Performance of HCs;
- Overview of HC system design, including maximum HC charge sizes;
- Standards and regulations.

The City and Guilds assessment comprises a theory multiple choice paper and a practical skills test. The 30 question theory paper covers the topics outlined above. For the practical assessment candidates must carry out the following tasks:

- Plan and prepare to repair a small HC system, including production of a risk assessment and a listing of PPE;
- Establish a safe work area;
- Calculate the capacity of a recovery cylinder;
- Recover HC from the system and purge with nitrogen;
- Un-braze a component and braze in a replacement;
- Pressure test for strength and leak tightness;
- Charge the system accurately;
- Ensure the system is working correctly;
- Seal and leak test the system;

[26] EN378-4:2008 A1:2012, E4

- Complete the relevant records.

The C & G 6187-21 HC certificate is a ‘Pathway Unit’. It is a stand-alone qualification at NVQ Level 2.

Appendix 1, Sources of Further Information

This table below provides details of organisations and publications for more information about various aspects of HC refrigerants.

Item	Website
Companies who provide products and services related to HC refrigerants	www.hydrocarbons21.com
Institute of Refrigeration Safety Code of Practice for systems utilising A2 and A3 refrigerants	www.ior.org.uk
Standards referenced in this Code	http://shop.bsigroup.com/
City and Guilds	www.cityandguilds.com
HC consultancy including simulated leak testing / area classification	www.coolconcerns.co.uk
HC training including C&G 6187-21 courses	www.coolconcerns.co.uk

Appendix 2, Standards and Regulations

ATEX is the name commonly given to the legal requirements for controlling explosive atmospheres and the suitability of equipment and protective systems used in them.

ATEX 95 (94/9/EC) covers the design of equipment and protective systems intended for use in potentially explosive atmospheres.

ATEX 137 (99/92/EC) covers the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. It applies, for example, to service engineers working on HC systems. DSEAR (Dangerous Substances and Explosive Atmosphere Regulations) is the UK implementation of ATEX 137. It also covers, for example, oxy acetylene brazing in the work place.

EN378 is not harmonised with the ATEX directive and it does not specify that ATEX applies, but it does reference other ATEX harmonised standards such as EN60079.

This Code provides guidance which follows the principles of ATEX with regard to flammable zone testing and avoidance of sources of ignition. Manufacturers should follow these principles and document all simulated leak testing, assumptions on leak rates, methods of reducing leakage potential and decisions regarding sources of ignition.

The following standards include guidance on HC systems.

Standard	**Title**	**Guidance (relevant to refrigerated cabinets using HC refrigerants)**
EN378-1:2008	Refrigerating systems and heat pumps – Safety and environmental requirements, Basic requirements, definitions, classification and selection criteria	HC systems >150g Practical limit Maximum charge sizes
EN378-2:2008	Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation	HC systems >150g High pressure protection Ventilated enclosures
EN378-3:2008	Refrigerating systems and heat pumps – Safety and environmental requirements, Installation site and personal protection	HC systems >150g Machinery rooms HC detectors
EN378-4:2008	Refrigerating systems and heat pumps – Safety and environmental requirements, Operation, maintenance, repair and recovery	HC systems >150g Repairs to HC systems Competence of personnel working on HC systems

EN60079-0:2009	Explosive atmospheres – Equipment – general requirements	Categorisation of flammable gases Classification of equipment Zones
EN60079-10-1:2009	Explosive atmospheres – Classification of areas – explosive gas atmospheres	Zones and classification of equipment Leak simulation testing V_z (volume of flammable zone) Air flow requirements
EN60079-14:2008	Explosive atmospheres – Electrical installations design, selection and erection	Location of sources of ignition Wiring
EN60079-15:2010	Explosive atmospheres – Equipment protection by type of protection "n"	Electrical equipment and enclosures for use in potentially flammable areas Labelling of electrical equipment
EN60335-1:2012	Household & similar electrical appliances – Safety Part 1: General requirements	HC Systems <150g Compliance with EN378
EN60335-2-24:2010	Household & similar electrical appliances – Safety Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances & ice-makers	HC systems <150g Compliance with EN378
EN60335-2-89:2010	Household & similar electrical appliances – Safety Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor	HC systems <150g Leak simulation testing for area classification Compliance with EN378
Institute of Refrigeration	Safety Code of Practice for Refrigerating Systems utilising A2 and A3 refrigerants	General guidance